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Abstract

The aims of this study were to examine multiple aspects of emotional processing in older adults with mild cognitive impairment (MCI) and to relate this potential impairment to both performances on tasks of executive functioning and working memory (EFWM) and social functioning. MCI is defined by the presence of cognitive deficiencies that do not meet criteria for a diagnosis of dementia. Many researchers believe that MCI is for some individuals an intermediate stage between normal aging and dementia and is potentially a marker for later dementia. The study of emotional processing is important not only because it provides information about the integrity of specific neural circuits, but also because this cluster of abilities has been linked to social functioning in persons with Alzheimer’s disease (AD). We compared the performances of 13 older adults with MCI and 15 healthy participants on tasks of emotion recognition, discrimination, and the identification of the intensity of emotion presented in facial expressions. We hypothesized that 1) those with MCI would perform more poorly than healthy participants on tasks requiring the recognition, discrimination, and rating of the intensity of facial affect; 2) performance on tests of EFWM would be related to affective processing and social functioning in both groups; and 3) affective processing would have an independent effect on social functioning above and beyond the contribution of EFWM.

We demonstrated that older adults with MCI performed more slowly and more poorly than healthy older adults on tasks requiring the recognition and discrimination of emotions. The healthy older adults were also more socially active and reported that they experienced less interference with social activity than those with MCI. In both groups, better executive functioning and working memory was significantly related to better emotion discrimination and more social functioning. In addition, reaction time on an emotional recognition task was
predictive of interference with social activities in both groups and of quality of life in the healthy participants.

The present findings may aide in identifying older adults at risk for increased loneliness or decreased quality of life. This research also has implications for earlier treatment of social aspects of MCI and improved family planning. Limitations of our study include our small sample sizes and the finding that our MCI group, which impaired relative to demographically matched controls, performed within normal expectations on tasks of memory and executive functioning.
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Introduction

Dementia, which is characterized by functional impairments in memory and at least one other cognitive domain (American Psychiatric Association, 2000), is a condition with high morbidity and mortality. Within this context, there is growing interest in mild cognitive impairment (MCI), a condition in which an older adult has an acquired cognitive deficit but does not meet criteria for a diagnosis of dementia (Petersen, 2004). Many researchers believe that MCI is an intermediate stage between normal aging and dementia in some individuals, and is potentially a marker for later dementia (Albert & Blacker, 2006; Gauthier et al., 2006; Grundman et al., 2004; Jicha et al., 2006; Petersen, 2004).

A number of studies have demonstrated that demented adults are impaired in the processing of emotion (Allender & Kaszniak, 1989; Kohler et al., 2005; Phillips, Scott, Henry, Mowat, & Bell, 2010; Spoletini et al., 2008; Sullivan & Ruffman, 2004; Weiss et al., 2008) in addition to their hallmark cognitive deficits. The study of emotional processing is important not only because it provides information about the integrity of specific neural circuits, but also because this cluster of abilities has been linked to social functioning in persons with a variety of neuropsychiatric disorders, including Alzheimer’s Disease [AD; (Greve, Cadieu, & Hale, 1994; Kohler et al., 2005)](Phillips, Scott, Henry, Mowat, & Bell, 2010) and those with schizophrenia (Mueser et al., 1996; Penn, Spaulding, Reed, & Sullivan, 1996). Despite this evidence, few studies have examined emotional processing in individuals with MCI. This study explored emotional
processing in adults with MCI and related performance in this domain to social functioning skills.

**Overview of Alzheimer's Disease**

AD is the most common variety of dementia, representing approximately 65% of all dementia cases (Kolb & Whishaw, 2003) and 35 to 60% of individuals evaluated for progressive dementias in a hospital setting (Cummings & Benson, 1992). By definition, dementia involves a decline in memory plus at least one other cognitive domain (American Psychiatric Association, 2000). Risk factors for dementia including greater age, lower educational or vocational achievement, positive family history, head injury, and possibly female gender (Kawas & Katzman, 1999; Miech et al., 2002; Mortimer et al., 1991; Saunders, Strittmatter, Schmechel, St. George-Hyslop, & et al., 1993; Serretti, Olgiati, & De Ronchi, 2007; Zandi et al., 2002; Zhang, Katzman, Salmon, Jin, & et al., 1990). Participation in mental and physical activity is a protective factor against developing dementia (Fratiglioni, Winblad, & von Strauss, 2007; Hultsch, Hertzog, Small, & Dixon, 1999; Kramer & Erickson, 2007).

Two of the primary cognitive characteristics of AD are difficulty with delayed recall together with rapid forgetting (Butters et al., 1988; Delis et al., 1991; Locasio, Growdon, & Corkin, 1995; Welsh, Butters, Hughes, Mohs, & Heyman, 1991). Individuals with AD are also more likely to produce intrusion errors on tests of verbal memory (Butters, Granholm, Salmon, Grant, & et al., 1987; Delis et al., 1991). This characteristic may be due to problems with both encoding (Delis et al., 1991) and consolidation (Martin, Brouwers, Cox, & Fedio, 1985). Other cognitive symptoms of AD include deficits in executive functioning (Bondi, Monsch, Butters, Salmon, & Paulsen,
1993; Duke & Kaszniak, 2000; Lafleche & Albert, 1995; Perry & Hodges, 1999; Salmon & Bondi, 2009), working memory (Duke & Kaszniak, 2000; Perry & Hodges, 1999), naming (Bayles & Tomoeda, 1983; Pollmann, Haupt, & Kurz, 1995; Salmon & Bondi, 2009), verbal fluency (Monsch, Bondi, Butters, Paulsen, & al, 1994; Monsch, Bondi, Butters, Salmon, & et al., 1992; Salmon & Bondi, 2009), and visuospatial abilities (Freedman et al., 1994; Locasio, Growdon, & Corkin, 1995; Mohr, Litvan, Williams, Fedio, & Chase, 1990).

The pathology of AD includes beta-amyloid plagues and neurofibrillary tangles. In the initial stages, these plaques and tangles are found in the entorhinal, transentorhinal, and hippocampal areas (Almkvist, 1999; Braak & Braak, 1991; Burns, 2002; Twamley & Bondi, 2003). They spread to the basal frontal, temporal, and occipital lobes (Braak & Braak, 1991). In addition to being related to early episodic memory impairment, these structures are proximal to the amygdala, an integral part of the limbic system which is involved in the recognition of affect. The amygdala also has many reciprocal connections to the hippocampus and aids in providing an emotional context for memories (Dere, Pause, & Pietrowsky, 2010; Markowitsch, Calabrese, Wurker, Durwen, & et al., 1994; Paré, 2003). Damage to the amygdala can cause impairment in the processing and recognition of affect in faces (Adolphs, 1999; Breiter et al., 1996; Calder et al., 1996; Young, 1996). In very early AD, reduced amygdala volume can be seen even before reductions in hippocampal volume (Mizuno, 2000). As early neuropathology accumulates in the regions surrounding the amygdala and limbic system, it is possible for individuals to demonstrate impairment in emotional recognition as well as mild impairment in
memory. This combination may lead to earlier detection of which individuals with MCI are more likely to later develop dementia and specifically, AD (Spoletini et al., 2008).

**Overview of MCI**

MCI is a condition in which an individual has subjectively and objectively impaired memory abilities or other cognitive functions, in the absence of a frank dementia. Many researchers believe that MCI may represent a transitional stage between normal aging and dementia or be a potential risk state for a later dementia (Albert & Blacker, 2006; Gauthier et al., 2006; Grundman et al., 2004; Jicha et al., 2006; Petersen, 2004). Estimates of conversion from aMCI to dementia, particularly to Alzheimer’s disease, range from 10% to 15% per year (Petersen, 2001). Conversion rates from aMCI to AD as high as 80% have been shown over a period of six years in data from the Mayo Clinic (Petersen, 2001). The prevalence rates of MCI ranged from 50% to 75% in a community sample; however, the authors noted that these rates were higher than previously expected and did not include or exclude participants based on reports of subjective memory complaints (Trittschuh et al., 2009), which have previously been documented to be 19% for those younger than 75 and 29% for those older than age 85 in a clinical cardiovascular study (Lopez et al., 2003). Therefore, there is strong evidence to suggest that the presence of MCI indicates that individuals are at high risk to develop later dementia (Mitchell & Shiri-Feshki, 2009). Several variants of MCI have been described in the literature. To have amnestic MCI (aMCI), an individual must demonstrate memory impairment, relative sparing of other aspects of cognitive functioning, generally intact activities of daily living, and not meet criteria for a diagnosis of dementia (Petersen, 2001). In addition, there is a multiple-domain amnestic variant of
MCI (aMCI-MD) in which an individual has impairments in memory and at least one other cognitive domain. Both of these variants will be included in our research study.

Individuals with MCI may experience a period of time of stable but poorer episodic memory followed by a more rapid decline in the years preceding a diagnosis of dementia (Backman, Small, & Fratiglioni, 2001; Chen et al., 2006; Lange et al., 2002; Small, Fratiglioni, Viitanen, Winblad, & Backman, 2000). They may have other cognitive symptoms such as decline in visuospatial abilities, executive functioning, and perceptual speed (Backman, Jones, Berger, Jonsson Luakka, & Small, 2005; Backman, Jones, Berger, Laukka, & Small, 2004; Matsuda & Saito, 2009; Storandt, Grant, Miller, & Morris, 2006; Twamley, Ropacki, & Bondi, 2006). In addition, some studies have shown decline in verbal memory skills including naming, category fluency, and vocabulary (Koenig, Smith, Moore, Glosser, & Grossman, 2007; Mickes et al., 2007; Powell et al., 2006).

**Emotional Processing in AD and MCI**

In order to have a complete understanding of the cognitive and neuropsychological profile of AD and MCI, it is necessary to study both memory and other nonmnemonic domains, such as language, executive functioning, emotional processing, and social functioning. The nonmnemonic domain that is the focus of the present study is emotional processing. A number of studies have shown that patients with AD are impaired in the processing of emotional information (Albert, Cohen, & Koff, 1991; Allender & Kaszniak, 1989; Bediou et al., 2009; Koff, Zaitchik, Montepare, & Albert, 1999; Kohler et al., 2005; Phillips, Scott, Henry, Mowat, & Bell, 2010; Spoletini et al., 2008; Sullivan & Ruffman, 2004; Weiss et al., 2008), which has been assessed
primarily with tasks that require the participant to infer affective information from images of other people's facial expressions. Other studies have found similar results with senile or demented older adults (Allen & Brosgole, 1993; Brosgole, Kurucz, Plahovinsak, & Gumiela, 1981; Brosgole, Kurucz, Plahovinsak, Sprotte, & Haveliwala, 1983; Cohen & Brosgole, 1988). The emotional processing deficits in these patients cannot be adequately accounted for by decline in cognitive functioning in several past studies. Emotional processing effects remained after using hierarchical regression to determine the effects of cognitive variables including facial recognition, naming, and auditory processing abilities (Allender & Kaszniak, 1989), after covarying facial recognition (Hargrave, Maddock, & Stone, 2002), and after using a linear regression to determine the amount of variance accounted for by overall cognitive mental status (Kohler et al., 2005). Greve and colleagues noted that while the ability to perceive oral prosody was related to satisfaction with expression of affection, language functioning was not related to this or any quality of life measure (Greve, Cadieuz, & Hale, 1994).

Emotional processing is important to examine because it may relate to an individual’s social functioning and quality of life. In a study of individuals with AD, Greve and colleagues (1994) showed that the patient's level of emotional processing was related to the quality of interpersonal functioning with the caregiving spouses. Two key findings were that the caregiver burden was disproportionately high for the spouses of patients with poorer facial affect perception, and that there was greater spousal dissatisfaction with the expression of affection and sexuality when the patient had poorer abilities to recognize emotional cues in speech (Greve, Cadieuz, & Hale, 1994). In adults with mild AD, the impairment in the processing of facial affect may influence
interpersonal relationships and quality of life (Kohler et al., 2005), and impairment in emotional perception in healthy older adults, those with AD, and those with late-life depression predicted quality of life for those individuals beyond the variance explained by cognitive factors and depression (Phillips, Scott, Henry, Mowat, & Bell, 2010). The relationship between emotional processing and social functioning are not specific to those with dementia, but rather is present across multiple populations. For example, in individuals with schizophrenia, there is strong evidence that emotional processing is related to quality of life and social functioning (Mueser et al., 1996; Pagulayan, Shear, Howe, Mohamed, & Foster, 2005; Penn, Spaulding, Reed, & Sullivan, 1996; Poole, Tobias, & Vinogradov, 2000).

Currently, very few studies have examined emotional processing ability in individuals with MCI (Fujie et al., 2008; Spoletini et al., 2008; Teng, Lu, & Cummings, 2007; Weiss et al., 2008). Teng and colleagues (2007) investigated whether patients with MCI (9 individuals with aMCI and 14 individuals with aMCI-MD) demonstrated impaired facial affect recognition, relative to 68 healthy participants, after adjustments for gender and age. The authors concluded that emotional processing deficits may be observed in individuals with MCI before AD has developed (Teng, Lu, & Cummings, 2007). Fujie and colleagues (2008) examined the role of the uncinate fasciculus (UF) in memory and emotional processing in patients with aMCI and healthy older adults. They showed that the left UF had lower fractional anisotrophy (FA) values in aMCI, meaning that they demonstrated greater white matter pathology in this region, and this result was correlated with memory performance in the same group. With regard to emotional processing, they demonstrated that patients with aMCI performed worse than healthy participants when
asked to recognize negative emotions and that the left UF anisotrophy were correlated with recognition of fear in the patients with aMCI. They surmised that it is possible that alterations in the UF early in the course of aMCI could be a potential cause of impairments in memory and emotional recognition in patients with aMCI (Fujie et al., 2008). Spoletini and colleagues (2008) reported that 50 individuals with aMCI had more difficulty recognizing low-intensity fearful expressions than did healthy individuals, but less difficulty than did those with AD. In individuals with aMCI, short-term memory impairment was the only significant predictor of this emotional processing impairment in a stepwise multiple regression using performance on this measure as the dependent variable and all of the cognitive variables as independent variables. A similar analysis in the individuals with AD showed that the single significant predictor of the same emotional processing deficit was a delayed verbal memory score (Spoletini et al., 2008). A recent study showed that, patients with aMCI-MD but not those with aMCI, were impaired on recognition of “overall emotions, sad, fearful, and neutral faces” (Weiss et al., 2008) and that level of depression influenced the recognition of emotion (Weiss et al., 2008). Both the patients with aMCI-MD and those with aMCI were mildly depressed, based on their performance on the geriatric depression scale (Weiss et al., 2008). Together, these studies suggest emotional processing deficiencies in MCI patients; however, the functional significance or clinical impact of the finding on everyday life remains unknown.

As discussed earlier, it is known from studies of non-MCI populations that emotional processing is an important predictor of social functioning. In addition, a number of studies have shown that cognitive abilities, including most prominently executive functioning (Burton, Strauss, Hultsch, & Hunter, 2006; Cahn-Weiner, Malloy, Boyle,
Marran, & Salloway, 2000; Johnson, Lui, & Yaffe, 2007) and memory (Allaire & Marsiske, 1999) influence a healthy or community-dwelling person’s daily functioning, as measured by their instrumental activities of daily living (IADLs), as well as more complex activities and skills including using the telephone, housework, social activities, and taking medications (Ward, Jagger, & Harper, 1998). In one study with older adults with healthy participants, those with AD, and those with late-life depression, executive functioning predicted emotional processing, which in turn predicted quality of life (Phillips, Scott, Henry, Mowat, & Bell, 2010). A similar relationship was demonstrated between executive functioning and emotional processing in MCI, in which executive functioning was determined to be the best cognitive predictor of performance on a test of discrimination of emotion in facial photographs (Teng, Lu, & Cummings, 2007). As executive functioning and memory have been shown to impact an individual’s everyday functioning and performance on emotional processing tasks, we plan to investigate the relationship between these cognitive skills and emotional processing and social functioning in MCI.

Aims and Hypotheses

The primary goal of this study was to compare the emotional processing skills of healthy older adults and those with MCI, exploring aspects of emotional processing that go beyond the facial affect recognition that have been the focus of most previous work. We hypothesized that those with MCI would perform more poorly on tasks requiring the recognition, discrimination, and rating of the intensity of facial affect than healthy participations. A second aim of the study was to confirm whether performance on tests of executive functioning and working memory would predict affective processing and social functioning, as has been shown in other populations. We hypothesized that performance
on tests of executive functioning and working memory would predict affective processing and social functioning in both groups. A third objective of this study was to determine the independent effect of affective processing on the prediction of social functioning after controlling for the effects of executive function and working memory. We hypothesized that affective processing would have an independent effect on social functioning above and beyond the contribution of executive functioning and working memory.

Method

Participants

Participants included thirteen older adults with a diagnosis of MCI and fifteen healthy older adults with no significant cognitive problems. Following procedure in the literature (Gabryelewicz et al., 2004; Goldberg et al., 2010; Loewenstein et al., 2009; Schmitter-Edgecombe & Creamer, 2010; van de Pol et al., 2007), all diagnoses were established through a semi-structured interview with the Clinical Dementia Rating [CDR; (Morris, 1993)]. In order to qualify for the study, each participant with MCI was required to receive a global rating of 0.5 based on the five domains on the CDR, which signified very mild or questionable dementing symptoms along with reporting subjective memory complaints. The healthy older adults were required to receive global ratings of 0 on the CDR, denoting no dementing symptoms. All participants were required to be age 60 or older, able to speak English fluently, able to provide the name of an informant willing to speak about his or her memory, and able to provide oral consent for the telephone pre-screening and written informed consent for the remainder of the protocol. Each of the participant’s medications were noted; they included medications for the treatment of seasonal allergies (1), anxiety (2), anticoagulants (3), arrhythmia (1), depression (1),
diuretic (7), acid reflux or ulcers (5), hair growth (1), hyperlipidemia (9), hypertension (16), hypothyroidism or thyroid replacement (6), inflammation or pain (4), memory (1), osteoporosis (1), overactive bladder (1), and sleep (1). Exclusion criteria for both groups included serious medical problems associated with cognitive disturbance, mental retardation (as estimated by the Peabody Picture Vocabulary Test – Fourth Edition) or a history of intellectual disability, a history of serious closed head injury with significant loss of consciousness or posttraumatic amnesia or other neurological illness or injury, a self-reported lifetime history of serious mental illness such as psychotic disorders, bipolar disorders, obsessive-compulsive disorders, Tourette’s syndrome, or a diagnoses of dementia and current usage of alcohol or drugs that impairs daily functioning or a lifetime history of alcohol or drug dependence.

**Data Collection Procedures**

The participants were recruited from past research studies with Dr. Robert Krikorian (co-investigator) and from the community via flyers and classified advertisements. Potential participants completed a telephone pre-screening, an in-person interview, and neuropsychological measures. The telephone screening was completed by the principal investigator and included obtaining oral consent to participate in the screening, conducting the CDR interview with the participant and an informant, the revised version of the Memory Impairment Screen by Telephone (MIS-T-R), and a portion of the clinical interview which included the participant’s medical and psychiatric history. After the telephone screening, the principal investigator and at least one psychologist reviewed the information and came to a consensus diagnosis for the potential participant. If it appeared that the potential participant met the study criteria, he
or she was then invited for an in-person interview and assessment, which was conducted
by the principal investigator, a trained graduate student, or a trained undergraduate
research assistant. At that time, the purpose of the study was reiterated and the participant
was asked to read and sign the consent form. Once written consent was obtained, the
principal investigator or another co-investigator obtained demographic information from
the participant and then administered the IQ estimate, the visual acuity task, the facial
recognition and memory task, the affective tasks, the memory task, the depression scale,
the working memory and executive functioning tasks, and the social functioning tasks.
The participants were compensated $40.00.

**Instruments**

**Diagnostic Measures**

The Clinical Dementia Rating [(CDR); (Morris, 1993)] was used to determine the
diagnosis of participants based on a clinician-administered, semi-structured interview
covering the domains of memory, orientation, judgment and problem solving, community
affairs, home and hobbies, and personal care. The interview includes information from
both the participant and an informant. In addition to the domains above, it requires both
the participant and informant to provide a description of recent events and compares the
descriptions for accuracy. The informant also offers information about potential areas of
cognitive or daily activities in which the participant has little insight into his or her
difficulties. The participant was rated on each domain and received an global overall
rating based on a published algorithm (Morris, 1993). The reliability and validity of this
instrument are acceptable (Burke et al., 1988; McCulla et al., 1989; Morris, McKeel,
Fulling, Torack, & Berg, 1988). Before the principal investigator administered the CDR,
she completed training and demonstrated high reliability with the online training system (http://alzheimer.wustl.edu/cdr/Application/Step1.htm). The MIS-T (Lipton et al., 2003) is an objective impairment instrument designed to be administered by phone for use in screening for cognitive impairment and consisting of a semantic memory task (cued word list). Dr. Robert Krikorian and colleagues revised the instrument to be more difficult and appropriate to use in combination with the CDR in order to screen for MCI. The MIS-T-R score was not used as an inclusion or exclusion criterion but to supplement the information obtained from the CDR to assist in reaching a diagnosis by providing additional information about the participant’s performance on an objective measure, which was compared with the information from the CDR. For example, a score between 7 and 12 on the MIS-T-R was usually suggestive of MCI, with higher scores indicating a possible lack of impairment and lower scores possible dementia.

**Neuropsychological Measures**

As individuals with MCI are known to demonstrate cognitive deficits in domains other than emotional functioning, this battery included tasks that were chosen to measure potential cognitive confounds that may have affected performance on the primary measures of interest. The neuropsychological measures are all well-validated, standardized clinical instruments on which the principal investigator completed training with a psychologist.

*Intellectual Functioning*

Intellectual functioning was estimated with the Peabody Picture Vocabulary Test – Fourth Edition [PPVT-4; (Dunn & Dunn, 2007)] which requires the participant to select from a group of four pictures the one that best represents a target word read by the
examiner; performance on this task is related to IQ. The standard score of the PPVT-4 was used to confirm that the participants had the intellectual capacity necessary to complete the tasks of interest.

**Facial Recognition and Motor Skills**

We used several subtests from the web-based Penn Computerized Neurocognitive Battery (PennCNP). The PennCNP facial memory task (Erwin, Gur, Gur, Skolnick, & al, 1992) was administered to assess facial recognition in the absence of an emotional processing demand to determine that any measured deficits in affect recognition were not due to deficiencies in processing faces. During the facial recognition test, the participant was shown a set of pictures of faces with each picture shown individually for 5 seconds. The participant was then shown a second set of pictures of faces and asked, for each face, if it was or was not shown as part of the first set. The number correct on this second set of faces was used as our metric on this task.

The motor task from the PennCNP battery (Erwin, Gur, Gur, Skolnick, & al, 1992) was used to measure visual acuity as well as to verify the participant’s ability to use a computer mouse. This task asked the participant to click on a green box that moved within the screen and that decreased incrementally in size. We measured the reaction time on this task.

**Executive Functioning and Working Memory**

Executive functioning was measured with the Trail Making Test, Part B [TMT; (Tombaugh, 2004)] and the Stroop test (Golden, 1978). The TMT asked the participant to sequentially connect a series of numbers and then alternating numbers and letters on paper; we administered Trail A to introduce the task but did not include it in our analyses.
Trail B requires concentration, mental flexibility, the ability to shift between sets, and the ability to hold the instructions in working memory. The Stroop task involved reading the color names printed in black, naming the color of the ink of a neutral design, and then naming the color of ink in which color names were printed; it measures the participant’s ability to inhibit an automatic reading response. We used normative t-scores of these tasks as our independent variables.

Scaled scores which were later converted to t-scores on the Letter-Number Sequencing from the Wechsler Adult Intelligence Scale – Fourth Edition [WAIS-IV; (Wechsler, 2008) were used to assess working memory; this subtest required the participant to listen to a list of letters and numbers and then to say them, in a numerical and alphabetical order, to the examiner; it examines the amount of information able to be held in working memory and the participant’s ability to manipulate this information. These assessments were used to determine the degree to which performance on tasks of executive functioning and working memory predicted performance on tasks of affect recognition and processing.

**Verbal Learning and Memory**

Verbal learning and memory was measured with the California Verbal Learning Test – Second Edition [CVLT-II; (Delis, Kramer, Kaplan, & Ober, 2000). It requires the participant to learn a set of 16 words over 5 trials and then to recall them after short- and long-delays. We included t-scores for the learning trials and z-scores for the short- and long-delay trials of this assessment as independent variables.

**Depression**
The Geriatric Depression Scale [GDS] is a self-report measure of symptoms of depression that includes a series of 30 yes/no questions. The number of questions answered in a direction suggestive of depression was counted. This measure was used to provide data about possible depressive symptoms that may have influenced the affective processing tasks.

**Affect Measures**

Emotional processing was assessed with the computer- and internet-based emotion subtests from the PennCNP battery, which is a validated battery of measures that assess aspects of facial affect recognition (Erwin, Gur, Gur, Skolnick, & al, 1992; Kohler, Bilker, Hagendoorn, Gur, & Gur, 2000; Silver, Shlomo, Turner, & Gur, 2002). On the Emotional Recognition (ER40) task, the participant was presented with a total of 40 images of men and women expressing facial expression consistent with each of five emotions (happy, sad, anger, fear, and no emotion/neutral). While each photograph was on the screen, the participant selected (via a mouse click) the button with the verbal label that best matched the emotion depicted in the face. On the Emotion Discrimination (EDF40) task, the participant was shown forty pairs of faces and indicated for each pair which face was happier or sadder (depending on the item), or if the faces were equally happy/sad. On the Emotional Acuity (PEAT40) subtest, the participant was shown forty photographs of men and women and chose how happy or sad the person in the picture was, based on a 7-point Likert scale ranging from “Very Sad” to “Very Happy.” For each task, the number correct and reaction time measures were collected. In addition, on the PEAT40 we collected the number of items that were within 1 degree of the correct intensity (i.e., moderately happy if the correct response was very happy).
Social Functioning Measures

The participants completed the UCLA Loneliness Scale (Russell, 1996), the Performance Outcomes Measures Survey: Social Functioning Survey [POMP-V; (American Association on Aging, 2004)] by the US Administration on Aging, and the Quality of Life Inventory [QOLI; (Frisch, 1994)] in order to obtain an estimate of the individual’s overall social functioning. The UCLA Loneliness Scale is a self-report measure of loneliness with reasonable validity and reliability (Russell, 1996). The minimum score on this measure is 20 and the maximum is 80, based on the degree (on a scale of 1 – 4) of 20 symptoms of loneliness endorsed by the participant. The POMP-V is a self-report instrument that measures an individual’s amount of social contact and activities by asking for the number of times a participant completed a certain activity, such as receiving a letter, within the past month; it consists of questions from the Older Americans Resources and Service (OARS), the OARS instrument has acceptable reliability and validity (American Association on Aging, 2004). While the minimum score on the main scale of this measure is 0 (no activity within the past two weeks), there is no maximum. For the question regarding present social activities, the participant could rate themselves as doing about enough (1), too much (2), or would like to be doing more (3). For the interference question, the participant is required to rate how much his or her physical or mental health interfered with social activities on a scale from not at all (1) to extremely (5). The QOLI is a self-report measure with adequate reliability and validity that assesses the degree to which a domain (such as family interaction) was rated as important to the individual, as well as how satisfied the participant was with his or her
functioning in that domain (Frisch, 1994). This instrument yields a t-score based on how satisfied an individual was in the life domains he or she considered important.

**Statistical Analysis**

Prior to our analyses, we used box plots of the data to identify data points which were extreme outliers; we removed these identified data points from our parametric analyses in order to prevent undue influence of the extreme outliers on the comparisons. In addition, all group differences were confirmed with non-parametric analyses (Mann-Whitney U) due to the small sample sizes. When the results are similar, we will be reporting the results of the parametric analyses. As our hypotheses are directional, that is, we believe that the MCI group will have poorer performances overall and that these poorer performance on executive functioning/working memory tasks and emotional processing tasks will lead to poorer social functioning, we used one-tailed analyses for our group differences and regressions. Statistical analyses included a series of t-tests to compare the group demographics and correlations to examine the relationships of the demographic and control variables with the emotional processing and social functioning variables. Due to our extremely limited variability within the healthy participants on ratings of physical or mental interference with social activity, we used a chi-squared analysis to compare the groups on this variable. No control variables related importantly to the primary measures of interest, so they were not incorporated into the final statistical models. To decrease the number of predictors for our regression analyses, we created a composite variable of executive functioning and working memory by converting the demographically corrected standard scores of the Letter-Number Sequencing subtest to a uniform metric and averaged this performance with performance on Trail B of the TMT.
and the interference score from the Stroop task. The group differences across the three emotional processing measures (facial affect recognition, discrimination, and identification of intensity) of the first hypothesis were tested with a series of t-tests. For the second hypothesis, correlations between the composite variable and the emotional processing and social functioning tasks were used to determine the extent to which the cognitive control tasks of executive functioning and working memory are associated with both emotional processing and social functioning. To investigate the third hypothesis, multiple regressions were also used to determine the extent to which emotional processing measures predicted social functioning after controlling for the cognitive control tasks. As performances on tasks of executive functioning and working memory were not significant predictors of social functioning within our preliminary regression models, we removed this term from later analyses in order to decrease our number of independent variables in the regression analyses.

Results

Demographic Variables

See Table 1 for descriptive statistics on the demographic variables. Regarding the participants’ relationship status, within the MCI group 31% were partnered, 8% were single, 23% were divorced, 23% were widowed, and 15% endorsed other relationship status; within the HP group 40% were partnered, 13% were single, 27% were divorced, 13% were widowed, and 7% reported other status. There was a significant group difference in sex ($t = 2.05$, $p = 0.03$) with the MCI group having significantly more males. As expected, the healthy older adults performed significantly better ($t = -3.93$, $p < .01$) on the MIS-T-R than the older adults with mild cognitive impairment. None of the
demographic variables correlated significantly and consistently (parametrically and non-parametrically and within each group) with any emotional processing or social functioning measures in both the MCI and HP groups.

Table 1

Demographic Information by Variable and Group

<table>
<thead>
<tr>
<th>Continuous Variables</th>
<th>Frequency Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>M</td>
</tr>
<tr>
<td>Age</td>
<td>MCI (N = 13)</td>
</tr>
<tr>
<td></td>
<td>HP (N = 15)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>MCI</td>
</tr>
<tr>
<td></td>
<td>HP</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory Impairment Screen by Telephone - Revised</td>
<td>MCI</td>
</tr>
<tr>
<td></td>
<td>HP</td>
</tr>
<tr>
<td>Peabody Picture Vocabulary Test - Fourth Edition</td>
<td>MCI</td>
</tr>
<tr>
<td></td>
<td>HP</td>
</tr>
<tr>
<td>Geriatric Depression Scale</td>
<td>MCI</td>
</tr>
<tr>
<td></td>
<td>HP</td>
</tr>
</tbody>
</table>

Cognitive Control Variables

Descriptive statistics for the cognitive control variables can be found in Table 2.

We found group differences on the learning ($t = -2.68$, $p = 0.01$), short-delay recall ($t = -2.84$, $p = 0.01$), and long-delay recall ($t = -2.86$, $p = 0.01$) trials of the CVLT-II, with the participants with MCI performing worse than the healthy participants. These differences
were expected due to the characteristics of mild cognitive impairment although the mean MCI group performances were still within the average range. We also found significant differences on three tasks of executive functioning and working memory with the MCI group again performing more poorly than the healthy participants; letter-number sequencing \((t = -3.36, p < 0.01)\), Trail B \((t = -3.43, p < .01)\), and the interference score of the Stroop task \((t = -2.20, p = 0.02)\); the mean performances for the MCI were similarly in the average range for these measures. In order to decrease the number of variables and later predictors, we created one composite variable for executive functioning and working memory by converting the demographically corrected standard scores to a uniform metric of a t-score and averaging the participants’ performances across these three tasks. We found that, as expected, the healthy participants performed better than the individuals with MCI on this composite variable \((t = -4.89, p < .01)\).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit of Measure</th>
<th>M</th>
<th>SD</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CVLT</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Verbal Learning</td>
<td>t-score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>57.7</td>
<td>11.5</td>
<td>57.0</td>
<td>41.0-76.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>67.1</td>
<td>5.5</td>
<td>67.0</td>
<td>56.0-76.0</td>
<td></td>
</tr>
<tr>
<td>Short-delay Recall</td>
<td>z-score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>0.7</td>
<td>0.8</td>
<td>0.5</td>
<td>0.0-2.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>1.4</td>
<td>0.6</td>
<td>1.5</td>
<td>0.5-2.5</td>
<td></td>
</tr>
<tr>
<td>Long-Delay Recall</td>
<td>z-score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>0.5</td>
<td>0.8</td>
<td>0.5</td>
<td>-0.5-1.5</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>1.2</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5-2.0</td>
<td></td>
</tr>
<tr>
<td><strong>Letter-number Sequencing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working Memory</td>
<td>scaled score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>8.6</td>
<td>1.1</td>
<td>9.0</td>
<td>6.0-10.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>10.9</td>
<td>2.3</td>
<td>11.0</td>
<td>8.0-16.0</td>
<td></td>
</tr>
<tr>
<td><strong>Trail Making Test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trail B</td>
<td>t-score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>44.5</td>
<td>8.0</td>
<td>44.0</td>
<td>34.0-59.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>55.0</td>
<td>8.2</td>
<td>54.0</td>
<td>43.0-75.0</td>
<td></td>
</tr>
<tr>
<td>Stroop Interference</td>
<td>t-score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>50.7</td>
<td>7.9</td>
<td>51.0</td>
<td>40.0-67.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>58.3</td>
<td>10.0</td>
<td>59.0</td>
<td>37.0-78.0</td>
<td></td>
</tr>
<tr>
<td><strong>Composite Executive &amp; Working Memory</strong></td>
<td>t-score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>48.9</td>
<td>5.0</td>
<td>47.2</td>
<td>37.2-56.7</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>55.4</td>
<td>4.3</td>
<td>55.4</td>
<td>47.6-63.4</td>
<td></td>
</tr>
<tr>
<td><strong>Penn Computerized Neurocognitive Battery</strong></td>
<td>milliseconds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Reaction Time</td>
<td>milliseconds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>948.9</td>
<td>125.2</td>
<td>968.5</td>
<td>679.5-1133.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>826.5</td>
<td>139.9</td>
<td>812.5</td>
<td>672.0-1164.0</td>
<td></td>
</tr>
<tr>
<td><strong>Facial Memory</strong></td>
<td>number correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>29.3</td>
<td>3.8</td>
<td>29.0</td>
<td>24.0-35.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>34.0</td>
<td>3.6</td>
<td>34.0</td>
<td>26.0-39.0</td>
<td></td>
</tr>
</tbody>
</table>
In addition, we demonstrated differences between groups in reaction time on a computerized motor task \((t = 2.39, p = 0.01)\), on which the MCI had longer reaction times, and the facial memory task from the PennCNP \((t = -3.34, p < .01)\), on which the participants with MCI made more errors than their healthy counterparts. There were no significant correlations between any of the cognitive control variables and performances on the emotional processing subtests or social functioning measures therefore we did not incorporate these variables into our later statistical models.

**Group Differences on Emotional Processing and Social Functioning Variables**

Table 3 contains the descriptive statistics for the emotional processing variables. We began by exploring the group differences across the primary emotional processing variables and their reaction times. The MCI group had a slower reaction time than the healthy participants on the task of emotional labeling (ER40RT; \(t = 2.47, p = 0.01\)). There were no significant group differences on the accuracy of any specific emotion (i.e., happy or sad) on the affect labeling task. There was a trend towards a significant difference in emotion discrimination (EDF40; \(t = -1.65, p = 0.055\)) on which the older adults with MCI made more errors than the healthy older adults; this comparison was significant non-parametrically \((U = 61.5, p = 0.048)\).
Table 3

*Descriptive Statistics for the Number of Correct Responses and Reaction Times on Each of the PennCNP Emotion Subtests.*

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>Median</td>
<td>Range</td>
</tr>
<tr>
<td><strong>Emotion Recognition (ER40)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number Correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>31.5</td>
<td>2.8</td>
<td>32.0</td>
<td>26.0-35.0</td>
</tr>
<tr>
<td>HP</td>
<td>32.3</td>
<td>2.6</td>
<td>33.0</td>
<td>28.0-38.0</td>
</tr>
<tr>
<td>Reaction Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>2714.9</td>
<td>531.2</td>
<td>2594.0</td>
<td>2086.0-3766.0</td>
</tr>
<tr>
<td>HP</td>
<td>2302.9</td>
<td>307.4</td>
<td>2300.8</td>
<td>1742.0-2953.0</td>
</tr>
<tr>
<td><strong>Emotion Discrimination (EDF40)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number Correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>21.3</td>
<td>5.6</td>
<td>23.0</td>
<td>9.0-28.0</td>
</tr>
<tr>
<td>HP</td>
<td>24.9</td>
<td>5.6</td>
<td>25.0</td>
<td>15.0-35.0</td>
</tr>
<tr>
<td>Reaction Time (Happy)</td>
<td></td>
<td></td>
<td></td>
<td>4781.0-12172.0</td>
</tr>
<tr>
<td>MCI</td>
<td>6633.9</td>
<td>2039.8</td>
<td>5609.0</td>
<td>3149.0-8563.0</td>
</tr>
<tr>
<td>HP</td>
<td>5948.0</td>
<td>1708.2</td>
<td>5938.0</td>
<td>336.0-8719.0</td>
</tr>
<tr>
<td>Reaction Time (Sad)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>6063.9</td>
<td>2002.6</td>
<td>5727.0</td>
<td>3180.0-10664.0</td>
</tr>
<tr>
<td>HP</td>
<td>5140.0</td>
<td>1628.5</td>
<td>4437.0</td>
<td>336.0-8719.0</td>
</tr>
<tr>
<td><strong>Emotional Acuity/Intensity (PEAT40)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number Correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>26.9</td>
<td>5.1</td>
<td>28.0</td>
<td>18.0-35.0</td>
</tr>
<tr>
<td>HP</td>
<td>24.8</td>
<td>5.7</td>
<td>26.0</td>
<td>11.0-34.0</td>
</tr>
<tr>
<td>Within 1 Correct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>38.4</td>
<td>1.9</td>
<td>39.0</td>
<td>33.0-40.0</td>
</tr>
<tr>
<td>HP</td>
<td>38.7</td>
<td>1.8</td>
<td>39.0</td>
<td>33.0-44.0</td>
</tr>
<tr>
<td>Reaction Time (Correct; msecs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>2822.5</td>
<td>499.0</td>
<td>2859.0</td>
<td>2242.0-4195.0</td>
</tr>
<tr>
<td>HP</td>
<td>2818.8</td>
<td>636.9</td>
<td>2765.0</td>
<td>1461.0-3922.0</td>
</tr>
<tr>
<td>Reaction Time (Within 1; msecs)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
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<td>2922.0</td>
<td>2242.0-4016.0</td>
</tr>
<tr>
<td>HP</td>
<td>3032.8</td>
<td>763.4</td>
<td>3078.0</td>
<td>1484.0-4672.0</td>
</tr>
</tbody>
</table>
See Table 4 for the descriptive statistics for the social functioning variables. The groups differed on the reported amount of social activity, with the healthy participants being more socially active than the older adults with MCI ($t = -2.66, p = 0.01$). The individuals with MCI, as a group, reported that their physical or mental health interfered with their amount of social functioning “a little bit,” while the healthy participants on average reported no such interference. The group difference in frequency of ratings was significant ($\chi^2(2, N = 25) = 29.12, p < 0.00$).
Table 4

Descriptive Statistics for the Scores on the Social Functioning Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Median</th>
<th>Range</th>
<th>Possible range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loneliness (raw scores)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>38.5</td>
<td>13.5</td>
<td>37.0</td>
<td>20.0-64.0</td>
<td>20.0-80.0</td>
</tr>
<tr>
<td>HP</td>
<td>38.3</td>
<td>7.1</td>
<td>39.0</td>
<td>29.0-51.0</td>
<td>20.0-80.0</td>
</tr>
<tr>
<td><strong>POMP-V (raw scores)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>48.6</td>
<td>19.9</td>
<td>48.0</td>
<td>17.0-81.0</td>
<td>0</td>
</tr>
<tr>
<td>HP</td>
<td>71.2</td>
<td>23.5</td>
<td>64.0</td>
<td>39.0-121.0</td>
<td>0</td>
</tr>
<tr>
<td>Present Level of Activity*</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>MCI</td>
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<td>1.0</td>
<td>2.0</td>
<td>1.0-3.0</td>
<td>1.0-3.0</td>
</tr>
<tr>
<td>HP</td>
<td>1.7</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0-3.0</td>
<td>1.0-3.0</td>
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<tr>
<td>Interference With Activity**</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>1.4</td>
<td>0.7</td>
<td>1.0</td>
<td>1.0-3.0</td>
<td>1.0-5.0</td>
</tr>
<tr>
<td>HP</td>
<td>1.0</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0-1.0</td>
<td>1.0-5.0</td>
</tr>
<tr>
<td><strong>QOLI (t-scores)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCI</td>
<td>48.9</td>
<td>12.1</td>
<td>54.0</td>
<td>24.0-65.0</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>52.7</td>
<td>10.9</td>
<td>53.0</td>
<td>27.0-75.0</td>
<td></td>
</tr>
</tbody>
</table>

*1=About enough, 2=Too much, 3=Would like to be doing more.
**1=Not at all, 2=A little bit, 3=Moderately, 4=Quite a bit, 5=Extremely

Executive Functioning and Working Memory as Predictors of Emotional Processing and Social Involvement and Satisfaction

In order to determine if emotional processing was associated with executive functioning and working memory, we conducted correlations between our composite variable and our emotional processing variables (emotion labeling, emotion discrimination, identification of emotional intensity and their reaction times) and the
social functioning tasks (loneliness, POMP-V, report of present activity on the POMP-V, Interference on the POMP-V, and quality of life). There were no group differences in the magnitude of the correlations between executive functioning/working memory and any of the emotional or social functioning measures. We found a trend towards a significant correlation between our composite variable and the performance on the emotion discrimination task ($r = 0.34, p = .08$) over both groups, this correlation was significant non-parametrically ($\rho = 0.45, p = 0.02$), please see Figure 1 for a depiction of this relationship.

![Figure 1](image.png)

*Figure 1*. The relationship between the composite variable and emotion discrimination. In addition, there was a significant correlation between the composite variable and the total POMP-V score, ($r = 0.43, p = 0.03$) over both groups, see Figure 2 for a representation of this relationship.
Figure 2. The relationship between the composite variable and amount of social activity.

**Emotional Processing as a Predictor of Social Functioning**

We conducted multiple regression analyses in order to determine whether the tasks of emotional processing predicted social functioning. The original third hypothesis called for analyses that examined the relationship between emotional and social functioning after accounting for the effects of executive functioning and working memory; however, because previous analyses failed to identify significant relationships between the executive functioning / working memory composite score and the measures of social functioning with the exception of the POMP-V total score, this variable was not retained in the final models. For each of the two emotional processing variables that was found to differ significantly or at a trend level between groups (ER40 reaction time and EDF40), we examined in separate analyses whether the emotion variable, group, or the emotion by group interaction predicted social functioning [loneliness, amount of social interaction (POMP-V), opinion of present amount of interaction (POMPPres), interference with social interaction (POMPInt), and quality of life].
This series of analyses revealed that the ER40 reaction time ($r = 0.37$, $t = 2.11$, $p = 0.02$) was a significant predictor of interference on the POMP-V that accounted for 14% of the variance of the interference ratings across both groups, see Figure 3 for a depiction of this relationship.

![Figure 3. The relationship between the reaction time on an emotion recognition task and the ratings of interference with social activity.](image)

There was neither a significant independent effect of group nor a significant group by RT interaction. This result suggests that a longer reaction time on the ER40 was related to reports of greater interference from physical or mental functions in a participant's social activity to a significant and similar degree across both groups. As we had limited variance on the ratings of interference within the healthy participants, we conducted a correlation between reaction time on the ER40 and ratings of interference only within the MCI group. There was a trend towards a significant relationship between longer reaction times on the emotion recognition measure and higher ratings of interference with social
functioning \((r = 0.54, p = 0.07)\), but it was not confirmed non-parametrically \((\rho = 0.35, p = 0.26)\). As reported above, reaction time on the motor task, which examined reaction time in the absence of emotional processing demands, was not significantly related to reports of interference or any other social functioning in prior analyses, so it was not included in this model.

Turning to the EDF40 as a predictor, the interference rating on the POMP-V was significantly predicted by group \((part r = -0.52, t = -2.83, p < 0.01)\) and performance on the EDF40 \((part r = 0.34, t = 1.83, p = 0.04)\) as the significant predictors, see Figure 4 for a representation of this relationship.

![Figure 4](image)

*Figure 4.* The relationship between the performance on an emotion discrimination task and the ratings of interference with social activity.

There was not a significant group by EDF40 interaction. This result suggests that the groups performed differently on the interference score of the POMP-V and that performance on the EDF40 predicts ratings of interference with social activities to a significant degree that is similar across the two groups. Because both ER40 and EDF40
were found to predict score on the POMP-V, we then included both emotion variables in a single model to explore unique variance. Reaction time on the ER40 (part $r = 0.40$, $t = 2.19$, $p = 0.02$) emerged as the single significant unique predictor of ratings of interference with social activities after taking into account performance on the other emotional processing measure.

We used a similar process to investigate the impact of the ER40 RT and the EDF40 on quality of life. The combination of ER40, group, and the group by ER40 interaction significantly predicted quality of life ($F(3,22) = 3.17$, $p = .02$). Reaction time on the ER40 (part $r = -0.39$, $t = -2.19$, $p = 0.02$) and the interaction term (part $r = 0.487$, $t = 2.69$, $p < 0.01$) were each significant unique predictors, see Figure 5 for a depiction of this relationship.

![Figure 5](image_url)

*Figure 5.* The relationship between reaction time on an emotion recognition task and quality of life.

In order to parse the nature of the interaction, we performed correlation analyses in each group separately. In the healthy participants, a longer reaction time on the ER40 was
counterintuitively predictive of a higher quality of life ($r = 0.73$, $p < 0.01$); this correlation showed a trend towards significance non-parametrically ($\rho = 0.49$, $p = 0.07$). In contrast, the relationship between ER40 RT and quality of life was not significant in the MCI group (partial $r = -0.45$, $t = -0.22$, $p = 0.83$). No other analyses between the reaction time on the ER40 or the performance on the EDF40 and the social functioning measures were significant.

**Discussion**

This study examined emotional processing and social functioning in older adults with and without MCI. We compared the participants’ emotional processing abilities by using tasks which required them to label emotion presented in a facial expression, discriminate between two faces to determine which was more emotionally intense, and to identify the intensity of an emotion over a seven-point scale. An analysis of the number of correct responses and primary reaction times on each emotional processing task revealed two main findings: first, that the older adults with MCI reacted more slowly than their healthy counterparts when asked to label emotions, and second, that there was a trend towards the healthy older adults making fewer errors than the participants with MCI when asked to judge which of two faces was happier or sadder if they were the same. This difference in reaction time offers an important methodological consideration for the interpretation of our and others’ research findings, as few studies have incorporated this variable and it may be sensitive to subtle differences in performance that are not apparent on accuracy measures. It may also have implications for the day-to-day life of individuals with MCI, because researchers have demonstrated that the average duration for a spontaneous emotional expression, and smiling in particular, is between one-half of a
second and four seconds long (Ekman & Friesen, 1982; Frank, Ekman, & Friesen, 1993; Hess & Kleck, 1990). As the average difference between the groups was slightly less than half a second, it may mean that individuals with MCI may be more likely to miss or not have enough time to interpret rapidly presented social cues in their everyday life. Similar to past research (Teng, Lu, & Cummings, 2007; Weiss et al., 2008), our findings included a trend towards poorer performance on a task of emotional discrimination or other emotional processing tasks by individuals with MCI as compared to healthy participants. Thus the results lend support to the presence of these deficiencies in patients with MCI that are consistent with reports in AD (Kohler et al., 2005; Phillips, Scott, Henry, Mowat, & Bell, 2010) While other researchers (Greve, Cadieuz, & Hale, 1994; Phillips, Scott, Henry, Mowat, & Bell, 2010) have investigated social functioning in individuals with dementia, few have examined the quality or quantity of interaction, that is, the amount of social interaction or satisfaction with that interaction, in individuals with MCI.

We investigated social functioning of older adults with and without MCI by measuring their degree of loneliness, their amount of social activity and their opinions about the sufficiency of this amount, and their self-ratings of quality of life. In our sample, participants with MCI reported engaging in fewer social activities within the past two weeks than healthy participants. To put this into context, research suggests that older adults in general participate in fewer social contacts or reduced social engagement than younger adults, while our sample of older adults with MCI were less engaged then their healthy counterparts; this decrease in activity may put them at risk for loneliness and other negative effects (Bailey, Henry, & Von Hippel, 2008). We also demonstrated a group difference in self-report of the degree to which physical or mental health interfered
with the amount of social activity, with the participants with MCI reporting greater interference with social activities. On average, participants who reported greater interference with social functioning also performed more poorly than healthy participants on tasks of executive functioning and working memory. This result is somewhat consistent with findings that suggest that decreased social activity and less functional independence were reported by individuals whose performance on neuropsychological assessments had declined from an initial assessment in a longitudinal study of rural community-dwelling older adults (Plehn, Marcopulos, & C.A., 2004).

We aimed to determine the relationship between performance on tests of executive functioning and working memory and those of emotional processing and social functioning. Specifically, we attempted to replicate and extend previous studies of emotional processing to different tasks of emotional labeling, discrimination, and identification of intensity of emotion as well as social functioning. When we analyzed the data from both groups using correlations to determine if our composite variable was related to those of emotional processing or social functioning, we found that better performance on tasks of executive functioning and working memory were, when taken together, significantly related to better performance on a task of discrimination of emotion between two faces. Our finding is indeed consistent with prior research suggesting that executive functioning was related to or predicted emotion discrimination and processing (Teng, Lu, & Cummings, 2007). It also is somewhat consistent with the previous finding that patients with aMCI-MD were more impaired on recognizing low-intensity facial expressions (fear) which was explained by short-term verbal memory impairment (Spoletini et al., 2008) as performance on emotional discrimination in our
battery was in part explained by working memory as included in our composite variable and both types of impairment were influenced or explained by a type of memory. In contrast to the research performed by Weiss and colleagues (2008), performance on the recognition of emotion was not influenced by the level of depression. The pattern of executive functioning predicting emotional processing tasks has also been found in older adults with AD (Phillips, Scott, Henry, Mowat, & Bell, 2010). Regarding social functioning, we found there was a significant relationship between the composite variable and the total amount of social activity on the POMP. This relationship is similar to the relationship between executive functioning and IADL’s proposed by Cahn-Weiner and colleagues (2000).

Similar to previous work in individuals with AD, we found predictive relationships between emotional processing and social functioning (Greve, Cadieu, & Hale, 1994; Phillips, Scott, Henry, Mowat, & Bell, 2010). While previous studies have examined this relationship in light of quality of life (Phillips, Scott, Henry, Mowat, & Bell, 2010) and caregiver burden (Greve, Cadieu, & Hale, 1994), we expanded the literature to include the amount social activity and, specifically, the participant’s self-rating of interference with their activity. We found that reaction time on the emotion recognition task predicted ratings of interference with social activities after accounting for group membership. In other words, slower reaction times predicted reports of physical or mental health causing greater interference with the participant’s ability to engage in social activities, and this correlation was similar across the two groups. A similar analysis with quality of life led to the counterintuitive finding that longer (i.e., more impaired)
reaction times in healthy individuals predicted better quality of life, an effect that was not present in the MCI group.

Our study, while it expands the existing literature, does have clear limitations. Most prominent is our small sample size, particularly for the older adults with MCI. A larger sample size would have increased our power to find smaller statistical effects and provided a larger basis for comparison to healthy participants. Another limitation is our subject selection. Overall, our sample of older adults with MCI was very high-functioning. This fact may have been biased due to our recruitment, which included advertisements placed in internet classified sections and our recruitment of community-dwelling individuals which may have selected for higher functioning individuals or those that are able to use the internet. In addition, we did not include performance on objective memory tasks as an inclusion or exclusion criteria, which is common to other studies of MCI (Teng, Lu, & Cummings, 2007; Weiss et al., 2008) as these measures are difficult to administer over the telephone and we did not have access to this information as many memory disorder clinics may have. Both our participant group and our healthy participant had relatively high levels of education, which may have created a bias towards better performance on cognitive testing. For example, a raw score of 65 seconds on Trail B for a 75 year-old, Caucasian male is equal to a t-score of 66 if he has 9 to 11 years of education but only to a t-score of 59 if he has 13 to 15 years of education (Heaton, Miller, Taylor, & Grant, 2004), thus adults with greater levels of education are expected to perform better on many cognitive tasks.

By using a semi-structured interview and rating as our main diagnostic criteria, we may have obtained a more heterogeneous sample of individuals with MCI. Our older
adults with MCI, on average, did not demonstrate impairment on objective tasks of learning and memory, executive functioning, or working memory, despite group differences. This pattern of performance may lead to a question of diagnostic accuracy in defining our MCI group. The group differences may have been impacted by the sexual demographics of our groups with the MCI group having more males, as there are sex differences in performance on the CVLT-II. For example, a raw score for the total learning trials, 1-5, of 40 is equal to a t-score of 54 for a 74 year-old man but to a t-score of 48 for a 74 year-old woman; women performed better than men overall in the normative sample (Delis, Kramer, Kaplan, & Ober, 2000). This bias would suggest that if our HP group had more males, they may have performed more poorly and this group difference may not have been significant. We also used standard scores that were corrected for this difference in performance so it is possible that our group difference would have remained if we had more males in the healthy group. In addition, we demonstrated group differences on the reaction time for the motor task and a facial memory task, but these performances were not significantly correlated to any measures of primary interest so we did not include them in the final regression models.

Although the MCI group was not impaired on this objective memory assessment (CVLT-II) as compared to the standardized norms, there are several lines of evidence that suggest their performance may represent a decline relative to their premorbid functioning. As our groups were relatively well matched for demographics, if we take the HP group as representative of what individuals with comparable age and education should achieve (i.e., performance in the high-average range), the MCI group was significantly more impaired that the HP group. Also, the MCI group did perform worse than the healthy
participants and below an informal cutoff on the MIS-T-R, suggesting impairment on a brief assessment of learning and memory. In order to merit a rating of 0.5 on the CDR, the participant demonstrated decline from previous abilities or impairment as rated by the participants and an informant. It is possible that a rating of 0.5 on the CDR captures a broad range of potential participants with higher specificity (includes a wider range of individuals with very mild dementia and may include those which would be ruled out by objective measures) than objective measures, depending on the clinic or community sample used in the study. Clinic-based samples are more likely to be impaired on objective measures because they have been referred due to reported memory problems. Individuals who may be included using this broader metric may differ on specific objective measures which use a finer metric with greater sensitivity. While the average performance on objective measures may not meet impaired levels, individual performance likely represents a decline from the participant's optimal previous abilities.

Despite our limitations, we demonstrated group differences for reaction time on an emotion labeling task and performance on a task of discrimination of emotion, the latter of which was predicted by performance on executive functioning and working memory. We also provided limited evidence that aspects of social functioning (ratings of present activity and interference with activity, loneliness, and quality of life) may be predicted by performance on emotional processing tasks in these populations. Future studies may have more success if they use stricter inclusion criteria for the patient group. By limiting enrollment based on neuropsychological test performance, researchers may be able to identify a purer sample of individuals with MCI. If they have a larger sample size of MCI, they may compare individuals with aMCI to those with aMCI-MD to
determine if group differences are present as compared to each other or healthy participants. Determining fine differences between groups may lead to greater diagnostic and prognostic information for these individuals. It may also be interesting to examine older adults with aMCI as compared to person with non-amnestic MCI to see if those with aMCI have greater difficulty in emotional processing or social functioning. If future studies in MCI are able to demonstrate impairment in emotional processing or social functioning, it could lead to earlier or improved identification of these individuals. Similarly, if longitudinal studies within this domain identify emotional processing as a predictor of which individuals with MCI may go to develop dementia, it may make possible earlier social interventions including improved family (medical and legal) planning or possible treatment with medication. If the relationship between executive functioning and working memory or emotional processing and social functioning is supported by future research, it may aid in identifying older adults at risk for increased loneliness or decreased quality of life. Improved social functioning may contribute to improved overall functioning for these older adults.
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